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Identification of Columbia Basin Sockeye Salmon Stocks Using Scale Pattern Analyses in 2000

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ABSTRACT

In 2000, representative samples of adult Columbia Basin sockeye salmon (*Oncorhynchus nerka*) were collected at Bonneville Dam as well as at Tumwater Dam on the Wenatchee River and Wells Dam in the mid-Columbia River downstream of the Okanogan River. These locations were chosen to provide samples of sockeye salmon from the two principle stocks of Columbia Basin sockeye salmon, which originate from the Wenatchee and Okanogan basins. Age composition for all samples was estimated. Four-year-old fish were estimated to comprise approximately 95% of the Bonneville Dam mixed-stock, 87% of the Okanogan known-stock (collected at Wells Dam), and 99% of the Wenatchee known-stock samples. Five-year-old fish were estimated to comprise approximately 1% of the Bonneville Dam mixed-stock, 5% of the Okanogan stock, and 1% of the Wenatchee stock samples. Three-year-old fish were estimated to comprise approximately 4% of the Bonneville Dam mixed-stock, 7% of the Okanogan stock, and 0% of the Wenatchee stock samples. Scale pattern analysis techniques were used to estimate that 56% of the Age 1.2 sockeye salmon, and 55% of the entire run, passing Bonneville Dam were of Okanogan stock, with the remainder of Wenatchee stock.

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INTRODUCTION

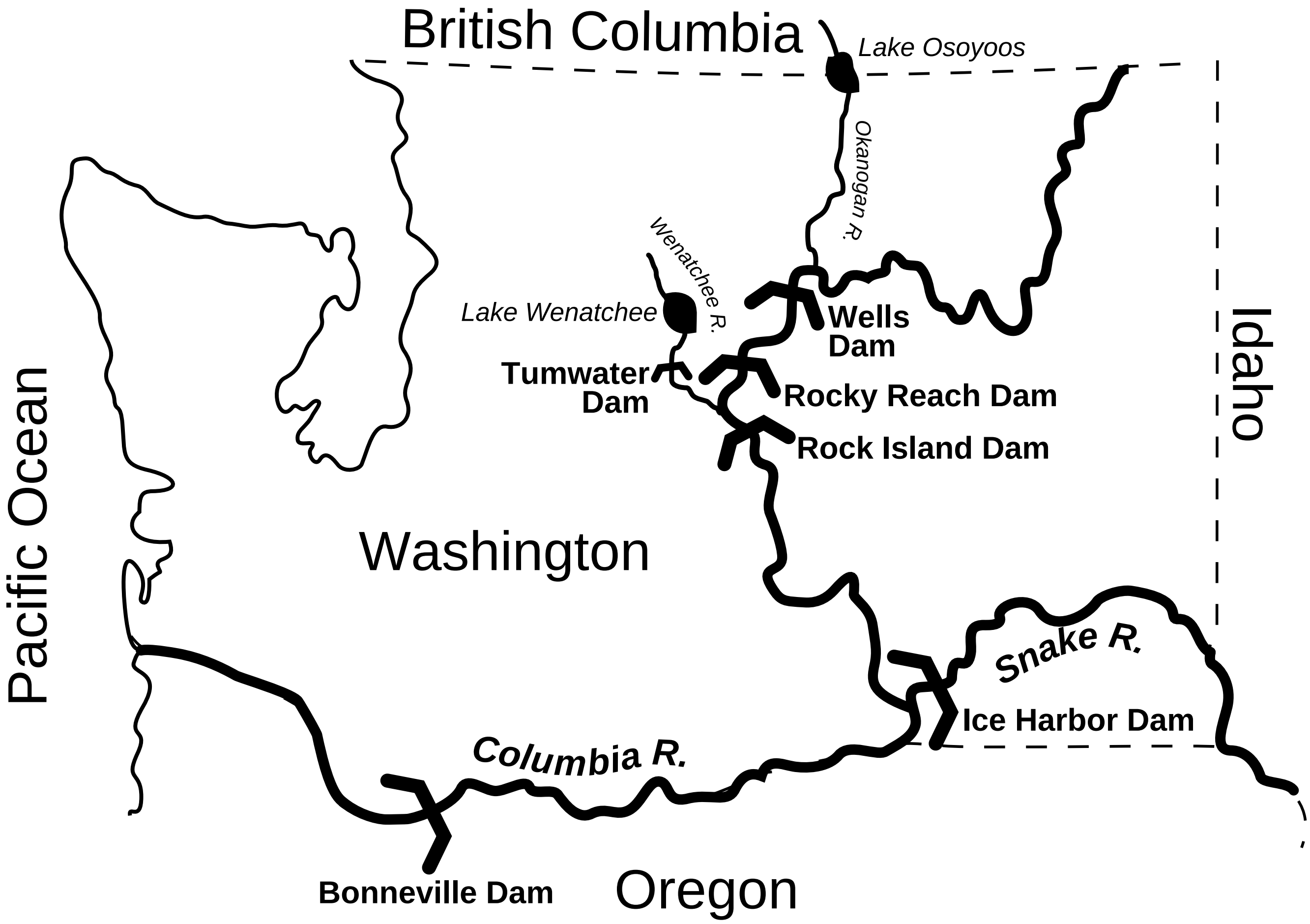
Sockeye salmon, *Oncorhynchus nerka,* is one of the five species of Pacific salmon native to the Columbia River Basin. Before white settlers developed the region, it is estimated the Columbia Basin supported an annual sockeye salmon run averaging over four million fish (Northwest Power Planning Council 1986, Fryer 1995). Since the mid-1800's, however, this sockeye salmon population has severely declined. The estimated number of sockeye salmon entering the Columbia River over the six years from 1994-1999 averaged only 21,700 fish per year (Fish Passage Center 2000).

The Columbia Basin sockeye salmon run was once composed of at least eight principal stocks (Fulton 1970, Fryer 1995). Today, only two major stocks remain[1] (Figure 1). From the 1960's through the early 1990's, both stocks were entirely naturally produced, originating in the Wenatchee River-Lake Wenatchee System (Wenatchee stock) and in the Okanogan River-Osoyoos Lake System (Okanogan stock). In recent years, enhancement programs in both systems have been initiated that capture returning adults, spawn the adults in hatcheries, and raise the offspring in net pens located in the rearing lakes before release (Hays 1992, Wells Project Coordinating Committee 1992). These two Columbia Basin sockeye salmon rearing areas differ markedly (Allen and Meekin 1980, Mullan 1986). Lake Wenatchee is oligotrophic, with relatively deep, cold, and biologically unproductive waters. Conversely, Osoyoos Lake has the shallow, warm, and agriculturally enriched waters characteristic of eutrophic lake habitats.

Reliable estimates of the overall run composition of Columbia Basin sockeye salmon stocks and the biological and migratory characteristics of each stock are useful for run-reconstruction studies permitting accurate population size forecasts, escapement monitoring, establishing spawner-recruit relationships, and developing discrete stock approaches to Columbia River mainstem harvest management. The Pacific Salmon Treaty (PST), ratified by

1 A small run of sockeye salmon return to the Snake River and are listed as endangered under the Endangered Species Act. While an estimated 93,391 sockeye salmon passed Bonneville Dam in 2000, only 214 (0.2%) passed Ice Harbor Dam on the Snake River.

Figure 1. Map of the Columbia Basin showing Bonneville, Rock Island, Rocky Reach, Tumwater, and Wells dams and the two principal river-lake systems that produce sockeye salmon stocks.



the United States and Canada in 1985 (PST 1985), requires that certain Pacific salmon populations be monitored to determine the influence of Treaty-imposed ocean harvest regulations on *transboundary* stocks. Some Okanogan-stock sockeye salmon originating in Canadian waters but migrating through, and harvested in, the United States portion of the Columbia River constitutes such a stock. Stock identification research would aid in estimation of the proportion and abundance of Canadian-origin sockeye salmon caught within the United States. This study, begun in 1987, was initiated to provide such information (Schwartzberg and Fryer 1988).

Scale pattern analysis (SPA) has been the method of study used for our stock identification research. SPA is a well-established stock identification and classification technique (Clutter and Whitesel 1956, Henry 1961, Mosher 1963, Anas and Murai 1969). In many species of fish, including Pacific salmon, the use of SPA as a tool for stock identification depends on a high correlation between individual fish growth and scale growth (Koo 1955, Clutter and Whitesel 1956). Fish growth and scale growth are influenced by genetic factors and by such environmental conditions as water temperature, length of growing season, and food availability. Stock identification based on SPA assumes that growth patterns will differ throughout a species' range and that these differences will be exhibited in the scales of entire groups or stocks of fish. Scale patterns from the Wenatchee and Okanogan sockeye salmon stocks in past years have differed (Schwartzberg and Fryer 1988, 1989, 1990; Fryer and Schwartzberg 1991, 1993, 1994; Fryer et al. 1992), presumably reflecting differences in freshwater rearing conditions. In most years, Okanogan sockeye salmon scale samples have shown greater growth to both freshwater annulus and saltwater entry than have Wenatchee sockeye salmon scale samples.

This report presents estimates of the age and length-at-age of adult Columbia Basin sockeye salmon in 2000. Weekly and composite age composition estimates for fish sampled at Bonneville Dam (mixed stocks of unknown origin) presented in this report are those found in a report detailing results from all CRITFC sampling activities at Bonneville Dam in 2000 (Kelsey and Fryer 2001). This report also presents age and length-at-age composition estimates from the Wenatchee stock collected at Tumwater Dam on the Wenatchee River and the Okanogan stock collected at Wells Dam. Low run sizes between 1995 and 1999 had resulted in the curtailment of our mid-

Columbia sockeye salmon sampling program at Wells and Tumwater dams. With the unexpectedly large run size in 2000, we resumed this program. Data collected from our mid-Columbia sampling program was used to estimate stock composition of the Bonneville Dam mixed stock in 2000.

METHODS

Sample Design

Sockeye salmon were sampled at Bonneville Dam one to two days per statistical week[2] in conjunction with a summer chinook salmon sampling program (Kelsey and Fryer 2001). Sampling at Tumwater and Wells dams was planned for one or two days per week during the period in which significant numbers of sockeye salmon were migrating past those sites. However, due to the early migratory timing of the 2000 sockeye migration, as well as delays in working out sampling logistics, sampling at Wells Dam did not begin until over half of the run had passed Wells Dam. The desired total sample size for age composition estimates at each site was a minimum of 500 fish at Bonneville Dam, and 300 fish at Tumwater and Wells dams (where the age composition is typically more skewed towards one or two age groups) which, in previous study years, has resulted in acceptable levels of precision and accuracy (Fryer 1995) ($d=0.05$, $\alpha=0.10$).

For SPA studies, the desired sample size was approximately 200 from each known-stock group for the predominant Age 1.2 age class (Conrad 1985). No adipose fin clipped fish were sampled at Tumwater Dam as those fish were needed for another research program.

A stratified sampling method that weighted weekly age and length-at-age estimates by actual migratory timing was used to obtain composite estimates for the Wenatchee and Okanogan known-stocks as well as the Bonneville mixed-stock (Cochran 1977).

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2 Statistical weeks are sequentially numbered calendar-year weeks. Excepting the first and last week of most years, weeks are seven days long, beginning on Sunday and ending on Saturday. In 2000 for example, Statistical Week 24 began on June 4 and ended on June 10.

Sampling Methods

Scales from mixed sockeye salmon stocks (or unknown-stocks) were obtained from fish sampled at the Bonneville Dam Adult Fish Facility, located at river km 235 on the mainstem Columbia River. Each stock was also sampled in terminal areas to obtain representative scale samples for each of the two Columbia Basin sockeye salmon groups (or known-stocks). Wenatchee stock scales were collected at Tumwater Dam on the Wenatchee River (river km 53), and Okanogan stock scales were obtained at Wells Dam on the mainstem Columbia River (river km 830).

Fish were trapped and anesthetized. Each fish was then sampled for scales, measured for fork length, inspected for markings and/or tag information and noted for other pertinent biological information (Kelsey and Fryer 2001). Inspection for biological information was not as extensive at Tumwater and Wells dams due to the need to quickly handle the fish which was required by other research projects being run concurrently by other parties. All fish were revived in freshwater and returned to the exit fishway. The only exception were some fish at Wells Dam that were retained for Cassimer Bar broodstock. Four scales per fish were collected to minimize the sample rejection rate. The gender of specimens collected at Bonneville Dam could not be determined because all were in the earliest stages of sexual maturation. The gender of some specimens collected at Tumwater and Wells dams could be determined, and was recorded.

Length Measurements

Fork lengths were measured to the nearest 0.5 cm. Mean lengths and measurements of variability were calculated for each age class, by weekly sampling period, and for the composite sample. Composite samples are post-stratified by weekly run size.

Age Determination

Scales were selected, mounted, and pressed according to methods described in Clutter and Whitesel (1956) and the International North Pacific Fisheries Commission (1963). Individual samples were visually examined and categorized using well-established scale age-estimation methods (Gilbert 1913, Borodin 1924, Van Oosten 1929). A sample of scales was sent to John Sneva of the Washington Department of Fish and Wildlife for corroboration of age estimates.

The European method for fish age description (Koo 1955) is used in this report. The number of winters a fish spent in freshwater (not including the winter of egg incubation) is described by an Arabic numeral followed by a period. The numeral following the period indicates the number of winters a fish spent in the ocean. Total age, therefore, is equal to one plus the sum of both numerals.

Scale Pattern Analysis

SPA of circuli in freshwater- and early saltwater-growth zones was used to identify each known-stock sample and to also classify mixed stock samples. The methodology was applied to the predominant Age 1.2 class from all stocks. Scale features were first measured using a computer and video camera based system (BioSonics Optical Pattern and Recognition System [OPRS]) that included a microscope (2x, 4x, 6.3x, and 10x objectives; a 1.0x, 1.25x, and 1.5x magnification changer; and a 2.5x photocompensation adapter), a secondary monitor (53 cm), and a digitizing tablet connected to a personal computer with a video frame-grabber board (BioSonics 1987). Acetate impressions of scales were placed in the microscope and projected onto the monitor using a 2.0x objective, 1.0x magnification changer, and 2.5x photo-compensation adapter. This lens configuration created a scale image initially viewed at 65x actual size.

Working from the top of the scale card, the first scale impression with no focus regeneration and clearly defined circuli was selected and the projected image was oriented diagonally with the clear (posterior) portion of the scale in the lower left corner of the screen. A reference line was drawn along the base of the scale image (Figure 2). The reference line was placed in the posterior field of the scale image so that the line bridged the end points of circuli in the first saltwater annulus (Fryer and Schwartzberg 1994). The objective was then changed to 10x, resulting in a viewed scale image 325x actual size, and a radial line was then drawn perpendicular to the reference line. Circuli positions were marked at the marginal (outermost) edge of their intersection with the radial line. The OPRS software (version 1.0) measured the distance from the scale focus to each circuli marker. The portion of the scale where circuli measurements were made included the entire freshwater zone and part of the early saltwater growth zone.

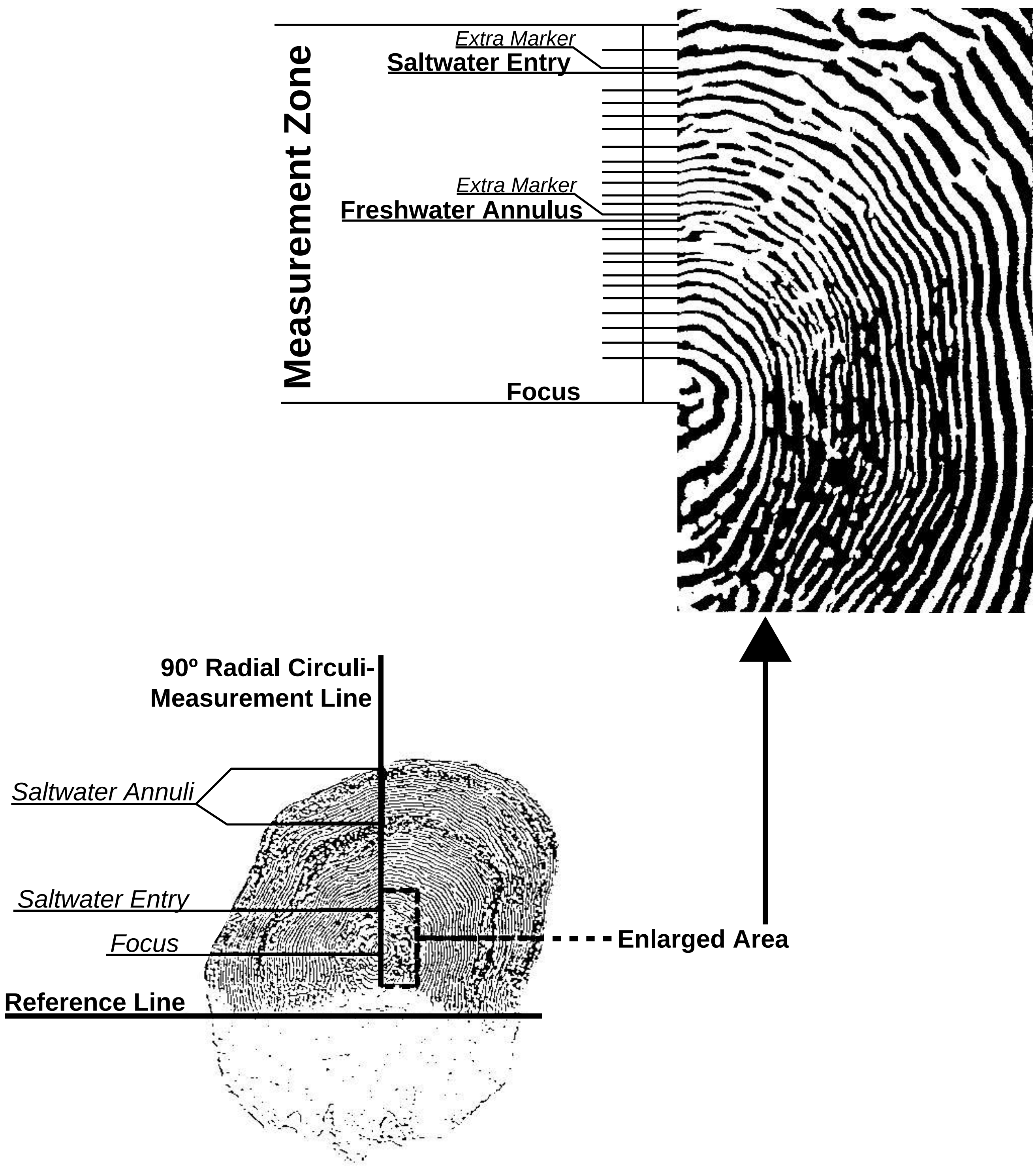
Additional artificial circuli markers were placed to permit measurement of other key scale-features, specifically, freshwater annulus and saltwater-entry point. These features were respectively indicated by two sets of closely spaced circuli markers. The 'extra markers' were placed immediately after and adjacent to the original circuli position markers and were interpreted and removed by data analysis programs used in subsequent procedures (Fryer and Schwartzberg 1993). The freshwater annulus-position marker was placed beside the last circulus in the freshwater annulus and the saltwater-entry marker was placed immediately after the first circulus in the ocean zone.

Statistical Analyses

A linear discriminant analysis technique developed by Fisher (1936) was used to differentiate stocks. Linear discriminant analysis permits the simultaneous use of many variables to form classification functions that typify and identify groups. This methodology has proven useful for determining the origins of individual fish stocks from mixed stock samples (Bethe and Krasnowski 1977, Bethe et al. 1980, Major et al. 1978).

Variables, composed of selected scale-measurements within the area from scale focus to Circulus 24, were tested to find those that most effectively characterized differences in growth between the two stocks. As in previous years' studies, distances between four adjacent circuli (or triplets) were the primary variable tested (Davis 1987). Distance measurements and number of

Figure 2. Age 1.2 Okanogan stock sockeye salmon scale showing growth and measurement zones.



circuli from scale focus to saltwater-entry and from scale focus to freshwater annulus margin (anterior) were also among the variables tested.

Accuracy of the discriminant analyses was determined by classifying the pooled known-stock samples from a particular analysis and then comparing results to actual (verifiable) known-stock identities. A jackknife procedure (Lachenbruch 1975, Dixon et al. 1983) was employed to correct for systematically biased results that are created in known-stock classification when the same samples are used for both calculating the discriminant function and estimating its accuracy. To correct for misclassification of unknown mixed stock samples, we used a method developed by Cook and Lord (1978) and Cook (1983). Variances on mixed stock classification estimates were also computed (Pella and Robertson 1979).

RESULTS

Sample Sizes

Final sample sizes used for age and length-at-age composition estimates were 557 Bonneville unknown-stock, 331 Wenatchee known-stock, and 286 Okanogan known-stock. Of the original 574 sockeye salmon sampled at Bonneville Dam, 3% of the total sample was rejected and not classified by age because of unreadable scales. For the same reason, 2% of the 337 Wenatchee, and 5% of the 301 Okanogan samples were rejected.

Age Composition

The predominant age class for both known- and unknown-stocks was Age 1.2. This age class was estimated to represent 94% of the Bonneville mixed-stock, 99% of the Wenatchee known-stock, and 87% of the Okanogan known-stock sample (for age details Tables 1-3).

Adipose clipped fish comprised 4.8% of the fish sampled at Bonneville Dam. These fish are most likely from the Wenatchee Eastbank supplementation program, although it is possible that a small portion could be from a Snake River program. One fish in Week 26 was identified as an Age 1.2 fish and had both an adipose and a left ventral fin clip. While sockeye salmon produced by the Okanogan River Cassimer Bar supplementation program have a ventral fin clipped, no known program or research would clip two fins on one sockeye salmon. Either the ventral or the adipose fin of this fish was likely removed by natural causes.

Table 1. Weekly and cumulative age composition Columbia Basin sockeye salmon sampled at Bonneville Dam in 2000.

					Age Composition by Brood Year and Age Class					
					1997	1996		1995		1994
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	1.1	1.2	2.1	1.3	2.2	2.3
22 - 23[a]	5/25, 6/1	9	9	645		0.889	0.111			
24	6/6, 8	85	84	4455		0.940		0.012	0.048	
25	6/14	74	69	16122		0.986		0.014		
26	6/20, 21	180	175	43848	0.029	0.960	0.006		0.006	
27	6/27, 29	120	118	18892	0.034	0.949		0.017		
28	7/5, 6	73	71	6069	0.099	0.901				
29	7/11,13	25	23	2280	0.087	0.870				0.043
30 - 31[b]	7/18, 20, 25	8	8	1083	0.750	0.125	0.125			
Cumulative		574	557	93394	0.037	0.945	0.005	0.006	0.005	0.001

a Weeks 22 and 23 were combined, due to small sample size (n=1) in Week 22.
b Weeks 30 and 31 were combined, due to small sample size (n=1) in Week 31.

Table 2. Weekly and cumulative age composition of Wenatchee sockeye salmon stocks sampled at Tumwater Dam in 2000.

					Age Composition by Brood Year and Age Class				
					1997	1996		1995	
Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	1.1	1.2	2.1	1.3	2.2
30[a]	7/21	84	83	17499		0.988			0.012
31	7/26, 27	203	199	2853		0.995			0.005
32[b]	8/2, 3	50	49	578		1.000			
Cumulative		337	331	20930		0.989			0.011

a Weekly run size includes fish numbers from Weeks 27 – 29. Sampling started in Week 30.
b Weekly run size includes fish numbers from Weeks 33 – 37. Sampling ended in Week 32.

Table 3. Weekly and cumulative age composition of Okanogan sockeye salmon stocks sampled at Wells Dam in 2000.

Statistical Week	Sampling Date	Number Sampled	Number Ageable	Weekly run size	Age Composition by Brood Year and Age Class: 1997				
					1997	1996		1995	
					1.1	1.2	2.1	1.3	2.2
29[a]	7/10	72	66	47323	0.045	0.895		0.045	0.015
30	7/17	129	125	7015	0.080	0.880			0.040
31	7/24	70	65	3355	0.185	0.800	0.015		
32[b]	7/31	29	29	2251	0.448	0.552			
Cumulative		300	285	59944	0.072	0.874	0.001	0.036	0.017

a Weekly run size includes fish numbers from Weeks 25 – 28. Sampling started in Week 29.
b Weekly run size includes fish numbers from Weeks 33 – 39. Sampling ended in Week 32.

Length Composition

Mean fork-lengths, calculated by age class, are generally greater among fish collected at Tumwater and Wells dams than those collected at Bonneville Dam3 (Tables 4-6). However, this difference is relatively small and many fish at sampled at Wells and Tumwater dams had well-developed secondary sexual characteristics, including the development of an elongated snout in the males resulting in an increase in fork length.

Classification of Known-Stock Samples

The variable set chosen to classify known- and unknown-stock samples consisted of triplets plus the distance and number of circuli to freshwater annulus. As in previous years, distance and number of circuli to saltwater entry variables were felt to be highly dependent on operator judgment as the location of saltwater entry was often difficult to determine. The freshwater annulus, on the other hand, was relatively easy to locate, and not nearly as subject to operator judgement.

The variables used by the stepwise procedure for the classification of Age 1.2 fish were the distances between the third and sixth circuli, the sixth and ninth circuli, eighteenth and twenty-first circuli, twenty-first and twenty-fourth circuli, and number of circuli to freshwater annulus. After application of the jackknife

3 Cumulative estimates may differ slightly from those previously reported in Kelsey and Fryer (2001). Statistical formulas, calculated in Kelsey and Fryer (2001) in such a way as to result in high round off effects, were corrected to calculate the cumulative estimates presented in this report.

Table 4. Length-at-age estimates for Columbia Basin sockeye salmon stocks sampled at Bonneville Dam in 2000. Composite estimates are weighted by weekly run size.

	Brood Year and Age Class					
	1997	1996		1995		1994
	1.1	1.2	2.1	1.3	2.2	2.3
Statistical Week 23						
Mean Fork Length (cm)		48.69	42.00			
Maximum		51.50	42.00			
Minimum		45.50	42.00			
Standard Deviation		2.42	0.00			
Sample Size		8	1			
Statistical Week 24						
Mean Fork Length (cm)		49.27		54.00	49.88	
Maximum		55.00		54.00	54.00	
Minimum		43.00		54.00	45.50	
Standard Deviation		2.34		0.00	3.50	
Sample Size		79		1	4	
Statistical Week 25						
Mean Fork Length (cm)		49.81		55.50		
Maximum		55.50		55.50		
Minimum		43.00		55.50		
Standard Deviation		2.49		0.00		
Sample Size		68		1		
Statistical Week 26						
Mean Fork Length (cm)	39.50	50.43	42.00		51.50	
Maximum	41.00	55.50	42.00		51.50	
Minimum	37.00	44.00	42.00		51.50	
Standard Deviation	1.87	2.06	0.00		0.00	
Sample Size	5	168	1		1	
Statistical Week 27						
Mean Fork Length (cm)	39.25	50.20		53.50		
Maximum	40.50	56.00		56.00		
Minimum	37.50	44.00		51.00		
Standard Deviation	1.50	2.31		3.54		
Sample Size	4	112		2		
Statistical Week 28						
Mean Fork Length (cm)	40.14	50.21				
Maximum	43.00	61.00				
Minimum	36.00	46.00				
Standard Deviation	2.53	2.59				
Sample Size	7	64				
Statistical Week 29						
Mean Fork Length (cm)	38.75	50.50				59.50
Maximum	39.00	56.00				59.50
Minimum	38.50	40.50				59.50
Standard Deviation	0.35	3.34				0.00
Sample Size	2	20				1
Statistical Week 30						
Mean Fork Length (cm)	38.80	53.50	39.00			
Maximum	41.00	53.50	39.00			
Minimum	37.00	53.50	39.00			
Standard Deviation	1.63	0.00	0.00			
Sample Size	6	1	1			
2000 Composite						
Mean Fork Length (cm)	39.36	50.20	41.00	54.13	50.20	59.50
Maximum	43.00	61.00	42.00	56.00	54.00	59.50
Minimum	36.00	40.50	39.00	51.00	45.50	59.50
Standard Deviation	1.83	2.16	1.73	2.25	3.11	0.00
Sample Size	24	520	3	4	5	1

Table 5. Length-at-age estimates for Wenatchee sockeye salmon stocks sampled at Tumwater Dam in 2000. Composite estimates are weighted by weekly run size.

	Brood Year and Age Class			
	1996		1995	
	1.2	2.1	1.3	2.2
Statistical Week 30				
Mean Fork Length (cm)	51.01			50.00
Maximum	55.50			50.00
Minimum	45.50			50.00
Standard Deviation	1.98			0.00
Sample Size	82			1
Statistical Week 31				
Mean Fork Length (cm)	50.99			52.00
Maximum	57.50			52.00
Minimum	45.00			52.00
Standard Deviation	2.20			0.00
Sample Size	198			1
Statistical Week 32				
Mean Fork Length (cm)	51.02			
Maximum	57.00			
Minimum	46.50			
Standard Deviation	2.36			
Sample Size	49			
2000 Composite				
Mean Fork Length (cm)	51.01			51.00
Maximum	57.50			52.00
Minimum	45.00			50.00
Standard Deviation	1.99			1.41
Sample Size	329			2

Table 6. Length-at-age estimates for Okanogan sockeye salmon stocks sampled at Wells Dam in 2000. Composite estimates are weighted by weekly run size.

	Brood Year and Age Class				
	1997	1996		1995	
	1.1	1.2	2.1	1.3	2.2
Statistical Week 29					
Mean Fork Length (cm)	40.17	50.33		55.67	49.00
Maximum	44.00	57.00		58.00	49.00
Minimum	36.00	43.00		53.00	49.00
Standard Deviation	4.01	2.97		2.52	0.00
Sample Size	3	59		3	1
Statistical Week 30					
Mean Fork Length (cm)	39.05	51.71			52.30
Maximum	42.00	59.00			55.00
Minimum	36.50	44.50			50.00
Standard Deviation	2.02	2.78			2.28
Sample Size	10	110			5
Statistical Week 31					
Mean Fork Length (cm)	38.38	50.66	40.00		
Maximum	41.00	57.50	40.00		
Minimum	35.50	45.00	40.00		
Standard Deviation	1.96	2.65	0.00		
Sample Size	12	52	1		
Statistical Week 32					
Mean Fork Length (cm)	38.08	50.81			
Maximum	41.00	55.00			
Minimum	35.50	47.50			
Standard Deviation	1.48	2.08			
Sample Size	13	16			
2000 Composite					
Mean Fork Length (cm)	39.28	50.52	40.00	55.67	51.75
Maximum	44.00	59.00	40.00	58.00	55.00
Minimum	35.50	43.00	40.00	53.00	49.00
Standard Deviation	3.97	2.96	0.00	2.52	2.44
Sample Size	38	237	1	3	6

procedure, 82.2% of the known-stock samples were accurately classified by this variable set (Table 7). Forty of 202 Wenatchee and 17 of 109 Okanogan, samples were misclassified.

Table 7. Known-stock classification tests using linear discriminant analyses with Age 1.2 Columbia Basin sockeye salmon stocks sampled in 2000.

		Sample Classification	
Stock	**Percent Correct**	***Wenatchee***	***Okanogan***
Wenatchee	80.2	162	40
Okanogan	84.4	17	92
Composite Accuracy	82.3		

Classification of Unknown-stock Samples

After weighting weekly stock composition estimates by weekly run size, 56% (σ=5%) of the non-adipose clipped Age 1.2 sockeye salmon were estimated to be Okanogan stock (Table 8). In an effort to derive a weekly and total stock composition estimate for all age classes, other age classes sampled at Bonneville Dam were allocated to the two stocks (Fryer 1995). Given the fact that no fish of Age 1.1, 2.1, and 1.3 were found in the known Wenatchee stock sample, these fish were allocated to the Okanogan stock. All adipose clipped fish were allocated to the Wenatchee stock as these are most likely fish from a Wenatchee supplementation program[4]. Although Age 2.2 fish were found in both Wenatchee and Okanogan known-stocks, these were allocated to the Okanogan stock, since they formed a larger portion of the larger stock. Among all sockeye passing over Bonneville Dam in 2000, we estimate that 55% (σ=5%) were of Okanogan stock.

4 Sockeye salmon raised as part of a Snake River supplementation program are also adipose clipped. However, the number of sockeye salmon returning to the Snake River is very small relative to those returning to the Wenatchee River.

Table 8. Stock composition estimates (%) of Columbia Basin sockeye salmon at Bonneville Dam in 2000.

Classification of only Age 1.2 Sockeye Salmon					
		Sample Classification			
Statistical	**Sample**	**Wenatchee**		**Okanogan**	
Week	**Size**	$\bar{x}$	s	$\bar{x}$	s
22-23	4	0	7	100	7
24	39	0	10	100	10
25	35	42	13	58	13
26	142	53	7	47	7
27	51	40	11	60	11
28	30	53	14	47	14
29-31	11	15	20	85	20
Population Estimate		**44**	**5**	**56**	**5**
Classification of Sockeye Salmon of all ages					
22-23	9	0	12	100	16
24	84	0	10	100	10
25	69	43	13	57	13
26	175	54	7	46	7
27	118	40	11	60	10
28	71	53	13	47	12
29	23	13	19	87	19
30-31	8	2	12	98	23
Population Estimate		**45**	**5**	**55**	**5**

DISCUSSION

The 2000 sockeye run of 93,394 fish at Bonneville Dam was the largest since 1988. The magnitude of this run is all the more surprising when one considers that over the previous 6 years (1994-1999) Bonneville Dam sockeye salmon counts totaled only 130,000 fish. By using fish counts at upstream dams it is possible to derive an estimate of the relative proportion of the run of Okanogan and Wenatchee origin. Using the count at Wells Dam of 59,944 sockeye salmon (which presumably are Okanogan stock), and the difference in Rocky Reach and Rock Island counts of 19,084 fish (which presumably turned into the Wenatchee River), the proportion of the run in the mid-Columbia of Okanogan origin was 76%. This differs from the estimate of 55% (±7%, 90% c.i.) presented in this report. In past years, our estimate of stock composition using scale patterns has normally been considerably closer than that estimated by inter-dam counts. There are a number of possible explanations for our study estimating a lower proportion of Okanogan sockeye salmon at Bonneville Dam than that estimated from dam counts. First is that Wenatchee stock sockeye salmon may have suffered greater mortality than Okanogan stock on their upstream migration through the hydrosystem. However, if this was the case, we would have expected to see many fish in poor condition at Tumwater Dam and this did not occur. Previous scale pattern work in other years has actually suggested that the Okanogan stock may tend to suffer greater mortality on the upstream migration (Fryer 1995). Another possibility could be that our known-stock samples did not adequately represent the Okanogan and Wenatchee stocks. Making this more likely is the fact that over 50% of the Okanogan run had passed Wells Dam prior to our beginning sampling. A third possibility has to do with the inherent inaccuracies in dam counts. The number of sockeye salmon passing Tumwater Dam as estimated by video counts was 20,929, which is greater than the 19,084 estimated by mainstem dam counts. Fallback at Rocky Reach Dam, whereby sockeye salmon pass upstream through the fish ladders then drop back over the dam via either the spillway or the turbines, only to reascend Rocky Reach (or to enter the Wenatchee River), could inflate the estimated percentage of Okanogan sockeye salmon.

The year 2000 was also unusual in the degree of dominance of the four-year-old portion of the run. Both the Bonneville Dam unknown-stock and the Wenatchee known-stock had the highest proportion of four-year-old fish of any year since this project began in 1985.

Research on Columbia Basin sockeye salmon will continue in 2001 and we will continue to develop an age, length-at-age, and stock composition data-base for this population. Data obtained from this program may be useful to monitor the impact of future main-stem Columbia fisheries, supplementation programs in the Wenatchee and Okanogan basins, as well as sockeye salmon stock recovery efforts in other Columbia River subbasins.

REFERENCES

Allen, R.L., and T.K. Meekin. 1980. Columbia River sockeye salmon study, 1971-1974. State of Washington, Department of Fisheries, Progress Report 120. Olympia.

Anas, R.E., and S. Murai. 1969. Use of scale characteristics and a discriminant function for classifying sockeye salmon *Oncorhynchus nerka* by continent of origin. International North Pacific Fisheries Commission Bulletin 26.

Bethe, M.L., and P.V. Krasnowski. 1977. Stock separation studies of Cook Inlet sockeye salmon based on scale pattern analysis. Alaska Department of Fish and Game Informational Leaflet 180. Juneau.

Bethe, M.L., P.V. Krasnowski, and S. Marshall. 1980. Origins of sockeye salmon in the Upper Cook Inlet fishery of 1978 based on scale pattern analysis. Alaska Department of Fish and Game Informational Leaflet 186. Juneau.

BioSonics, Inc. 1987. Optical pattern recognition system. Data acquisition program manual. Seattle, Washington.

Borodin, N. 1924. Age of shad *Alosa sapidissima* (Wilson) as determined by the scales. Transactions of the American Fisheries Society 54:178-184.

Clutter, R., and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. International Pacific Salmon Fisheries Commission Bulletin 9.

Cochran, W.G. 1977. Sampling techniques. J.W. Wiley & Sons. New York.

Conrad, R. 1985. Sample sizes of standards and unknowns for a scale pattern analysis. Alaska Department of Fish and Game, Sports Fisheries Division Unpublished Memorandum. Anchorage.

Cook, R.C. 1983. Simulation and application of stock composition estimators. Simulation and application of stock composition estimators. Canadian Journal of Fisheries and Aquatic Sciences. 40: 2113-2118.

Cook, R.C., and G.E. Lord. 1978. Identification of stocks of Bristol Bay sockeye salmon *Oncorhynchus nerka*, by evaluating scale patterns with a polynomial discriminant method. United States Fish and Wildlife Service Fishery Bulletin 76(2):415-423.

Davis, N.D. 1987. Variable selection and performance of variable subsets in scale pattern analysis. (Document submitted to annual meeting of the

International North Pacific Fisheries Commission 1987). Fisheries Research Institute, University of Washington, Report FRI-UW-8713, Seattle.

Dixon, W.J., M.B. Brown, L. Engelman, J.W. Frane, M.A. Hill, R.I. Jennrich, and J.D. Toporek. 1983. BMDP Statistical Software. University of California Press, Berkeley.

Fish Passage Center. 2000. U.S. Army Corp of Engineers. On-line at: http://www.nwp.usace.army.mil/op/fishdata/adultfishcounts/BON_200_YTD.txt

Fisher, R.A. 1936. The use of multiple measurements in taxonomic problems. Annals of Eugenics 7:179-188.

Fryer, J.K. 1995. Columbia Basin sockeye salmon: Causes of their past decline, factors contributing to their present low abundance, and the future outlook. Ph.D. Thesis. University of Washington, Seattle.

Fryer, J.K., C.E. Pearson, and M. Schwartzberg. 1992. Identification of Columbia Basin sockeye salmon stocks using scale pattern analyses in 1991. Columbia River Inter-Tribal Fish Commission Technical Report 92-2, Portland, Oregon.

Fryer, J.K., and M. Schwartzberg. 1991. Identification of Columbia Basin sock-eye salmon stocks based on scale pattern analyses, 1990. Columbia River Inter-Tribal Fish Commission Technical Report 91-2, Portland, Oregon.

Fryer, J.K., and M. Schwartzberg. 1993. Identification of Columbia Basin sock-eye salmon stocks scale pattern analyses in 1992. Columbia River Inter-Tribal Fish Commission Technical Report 93-2, Portland, Oregon.

Fryer, J.K., and M. Schwartzberg. 1994. Age and length-at-age composition of Columbia Basin spring and summer chinook at Bonneville Dam, 1993. Columbia River Inter-Tribal Fish Commission Technical Report 94-1, Portland, Oregon.

Fulton, L.A. 1970. Spawning areas and abundance of steelhead trout and coho, sockeye, and chum salmon in the Columbia River Basin–past and pre-sent. National Marine Fisheries Service Special Scientific Report (Fisheries) 618.

Gilbert, C.H. 1913. Age at maturity of the Pacific coast salmon of the genus *Oncorhynchus*. United States Bureau of Fisheries Bulletin 32:1-22.

Hays, S. 1992. Rock Island Hatchery evaluation plan and 1992-93 work plan. Memorandum to Rock Island Coordinating Committee, June 5, 1992. Public Utility District No. 1 of Chelan County, Wenatchee, WA.

Henry, K.A. 1961. Racial identification of Fraser River sockeye salmon by means of scales and its applications to salmon management. International Pacific Salmon Fisheries Commission Bulletin 12.

International North Pacific Fisheries Commission. 1963. Annual Report – 1961. Vancouver, British Columbia.

Kelsey, D. A. and J.K. Fryer. 2001. Age and length composition of Columbia Basin chinook, sockeye, and coho salmon at Bonneville Dam in 2000. Columbia River Inter-Tribal Fish Commission Technical Report 01-01. Portland, Oregon.

Koo, T.S.Y. 1955. Biology of the red salmon, *Oncorhynchus nerka* (Walbaum), of Bristol Bay, Alaska, as revealed by a study of their scales. Ph.D. thesis, University of Washington, Seattle.

Lachenbruch, P.A. 1975. Discriminant analysis. Hafner Press, New York, New York.

Major, R.L., J. Ito, S. Ito, and H. Godfrey. 1978. Distribution and origin of chinook salmon *Oncorhynchus tshawytscha* in offshore waters of the North Pacific Ocean. International North Pacific Fisheries Commission Bulletin 38.

Mosher, K.H. 1963. Racial analysis of red salmon by means of scales. International North Pacific Fisheries Commission Bulletin 11.

Mullan, J.W. 1986. Determinants of sockeye salmon abundance in the Columbia River, 1880s – 1972: a review and synthesis. United States Fish and Wildlife Service Biological Report 86(12).

Northwest Power Planning Council. 1986. Council staff compilation of information on salmon and steelhead losses in the Columbia River Basin. 850 SW Broadway, Portland, Oregon.

PST (Pacific Salmon Treaty). 1985. Treaty between the government of the United States of America and the government of Canada concerning Pacific salmon. Treaty document Number 99-2, (entered into force March 18, 1985), 16 USC§§3631-3644 (1988).

Pella, J.J., and T.L. Robertson. 1979. Assessment of composition of stock mixtures. United States Fish and Wildlife Fishery Bulletin 77(2):387-398.

Schwartzberg, M. and J.K. Fryer. 1988. Identification of Columbia Basin sockeye salmon stocks based on scale pattern analyses, 1987. Columbia River Inter-Tribal Fish Commission Technical Report 88-2, Portland, Oregon.

Schwartzberg, M. and J.K. Fryer. 1989. Identification of Columbia Basin sockeye salmon stocks based on scale pattern analyses, 1988. Columbia River Inter-Tribal Fish Commission Technical Report 89-2, Portland, Oregon.

Schwartzberg, M. and J.K. Fryer. 1990. Identification of Columbia Basin sockeye salmon stocks based on scale pattern analyses, 1989. Columbia River Inter-Tribal Fish Commission Technical Report 90-2, Portland, Oregon.

Van Oosten, J. 1929. Life history of the lake herring, *Leucichthys artedi* (Le Sueur) of Lake Huron as revealed by its scales, with a critique of the scale method. United States Bureau of Fisheries Bulletin 44:265-428.

Wells Project Coordinating Committee. 1992. Summary of December 1 1992 Meeting. Public Utility District No. 1 of Douglas County, East Wenatchee, WA.